THE UNIVERSITY OF ALBERTA

A STUDY OF ALBERTA ASPHALTS

A THESIS

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DEGREE OF MASTER OF SCIENCE

CIVIL ENGINEERING

by

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ABSTRACT

The object of this thesis was to examine Alberta refined asphalts from their beginning in the refinery to the use in a pavement structure. This was done by means of literature study, a questionnaire form and a representative sample of 150-200 penetration grade asphalt cement from five of the six asphalt producing refineries in Alberta.

A critical analysis was made of a majority of the current asphalt cement tests being used to control the uniformity, consistency and quality of the asphalt cement at the refinery and ultimately in the pavement structure.

The testing program set up in conjunction with the four asphalt cement samples served a two-fold purpose. It was used to identify and measure the inherent physical properties of the asphalt, plus being used to assess each asphalt, on a comparative basis to a few so-called quality tests. Assessment on this basis was necessitated because correlation of pavement performance data to test results were not available.

The results of the study showed that among the four asphalt cements tested some were found to out-perform others in relation to a few so-called quality tests. These differences in results were thought to be due to the source and mixture of the petroleum crude oils used in the production of each asphalt.

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CHAPTER I

INTRODUCTION

As a result of expanded highway programs to accommodate our growing traffic load, and increased airport construction to meet the needs of increasing air traffic there has been an increased emphasis on better pavement construction. Pavements in this connotation may be sub-divided into two classes, rigid pavements and flexible pavements. Throughout this thesis any mention of pavement or pavements will refer only to a flexible pavement of which asphalt is the principal component. Therefore, in order to produce a better pavement a thorough knowledge of the constituents involved in the pavement must be understood by those directly involved in its design and ultimate construction.

Considering only the upper portion of a pavement structure the two constituents involved in its construction are asphalt and aggregate. The prime objective of this thesis will be to present a comprehensive discussion of asphalt as one of the constituents in a flexible pavement. This discussion will involve the methods used in its production, problems that may be encountered from its use in a pavement structure, its composition, physical properties, and the specifications that are used to control it. Consideration will also be given to its use and its relative

importance to the petroleum refining industry in Alberta.

Throughout this discussion, the terms "asphalt" and "asphalt cement" are synonymous, as are bituminous pavement and asphalt pavement.

CHAPTER II

BACKGROUND

This chapter briefly presents an insight into the status of asphalt in Alberta. It is impossible to make this picture complete without some reference to the asphalt phase in the rest of Canada. Since practically all asphalt is now obtained from petroleum crude oil by one or another refining process, consideration must also be given to both Alberta and Canadian crude oil sources and refineries.

1. CANADIAN OIL SITUATION

The term "situation" as used in this chapter will refer to a general state in reference to production and refining figures.

Canadian crude oil supplies are found mainly in the prairie provinces, while major markets are located in the eastern provinces. The long distance between the two presents difficulties and at the present time refineries in Quebec and the Maritimes find it more economical to process crude oil from the Middle East and Venezuela than Canadian crudes. Broadly speaking therefore, refineries in the Toronto area and west are processing Canadian crudes, while refineries in Montreal and in the east are processing imported crudes.(1)*

*Numbers in parentheses ( ) refer to the bibliography.

Transportation of Canadian petroleum crude oil and imported crudes is accomplished by means of pipelines connecting western Canada to eastern Canada and Portland to Montreal, respectively.

In 1959 Canada's production of crude oil was 508,000 barrels per day, while its refining capacity was 872,000 barrels per day.[1, 2] By spring of 1960 the capacity figures reached 963,350 barrels per day.

2. CANADIAN ASPHALT

Refineries with asphalt producing facilities are wide spread across Canada. Table I elaborates on this fact.[1] The same is true here as was the case with the oil refineries. The eastern refineries produce asphalt from Venezuelan and Middle East crudes while the refineries in Ontario and west produce asphalts from Canadian crudes.

The total Canadian market in 1959 was approximately nine million barrels, while the producing facilities could have produced over fifteen million barrels. The reason for this rather large discrepancy is the seasonal demand for asphalt for road making purposes. Figure I shows asphalt consumption in Canada over the last twenty years. Although the consumption has not been consistent from year to year it appears that since 1955 the demand has been growing at an annual rate of 8 per cent.

3. ALBERTA OIL AND ASPHALT

From Figure 2 the crude oil produced and refined in Alberta is shown over the years from 1947 to 1959. Alberta's crude oil production reached a maximum of one hundred and forty-three million barrels per

TABLE I

REFINERY ASPHALT PRODUCING FACILITIES IN CANADA AS AT DECEMBER 31, 1959

1000 B/D

Refinery Location	Crude Source	Crude Capacity	Asphalt Producing Facilities	Total Asphalt Produced
Nova Scotia				
Halifax	Venezuela	49.0	1.8	1.8
Quebec				
Montreal	Venezuela & Middle East	5.0	9.0	
Montreal	Venezuela	71.8	3.6	
Montreal	Venezuela & Middle East	62.0	6.0	18.6
Ontario				
Clarkson	Western Canada	61.5	4.0	
Fort William	Saskatchewan	4.0	0.8	
Sarnia	Western Canada & Ontario	94.0	2.2	7.0
Manitoba				
Winnipeg	Western Canada	18.0	0.8	0.8
Saskatchewan				
Moose Jaw	Alberta & Sask.	15.0	1.2	
Moose Jaw	Saskatchewan	3.0	0.9	
Regina	Alberta & Sask.	22.5	0.2	
Saskatoon	Alberta & Sask.	8.0	0.3	
Kamsack	Saskatchewan	1.0	0.3	2.9
Alberta				
Calgary	Alberta	7.5	0.6	
Lloydminster	Alberta	8.5	3.2	
Lloydminster	Alberta	4.0	2.0	
Calgary	Alberta	14.7	0.9	
Edmonton	Alberta	28.5	0.8	
Wainwright	Alberta	4.5	1.2	8.7
British Columbia				
Ioco	Alberta	32.0	0.6	
Kamloops	Alberta	5.0	0.7	
Shell-Burn.	Alberta	21.5	2.0	
Burnaby	Alberta	18.0	2.0	
Dawson Creek	British Columbia	2.5	0.4	5.7
			Total Canada	43.6

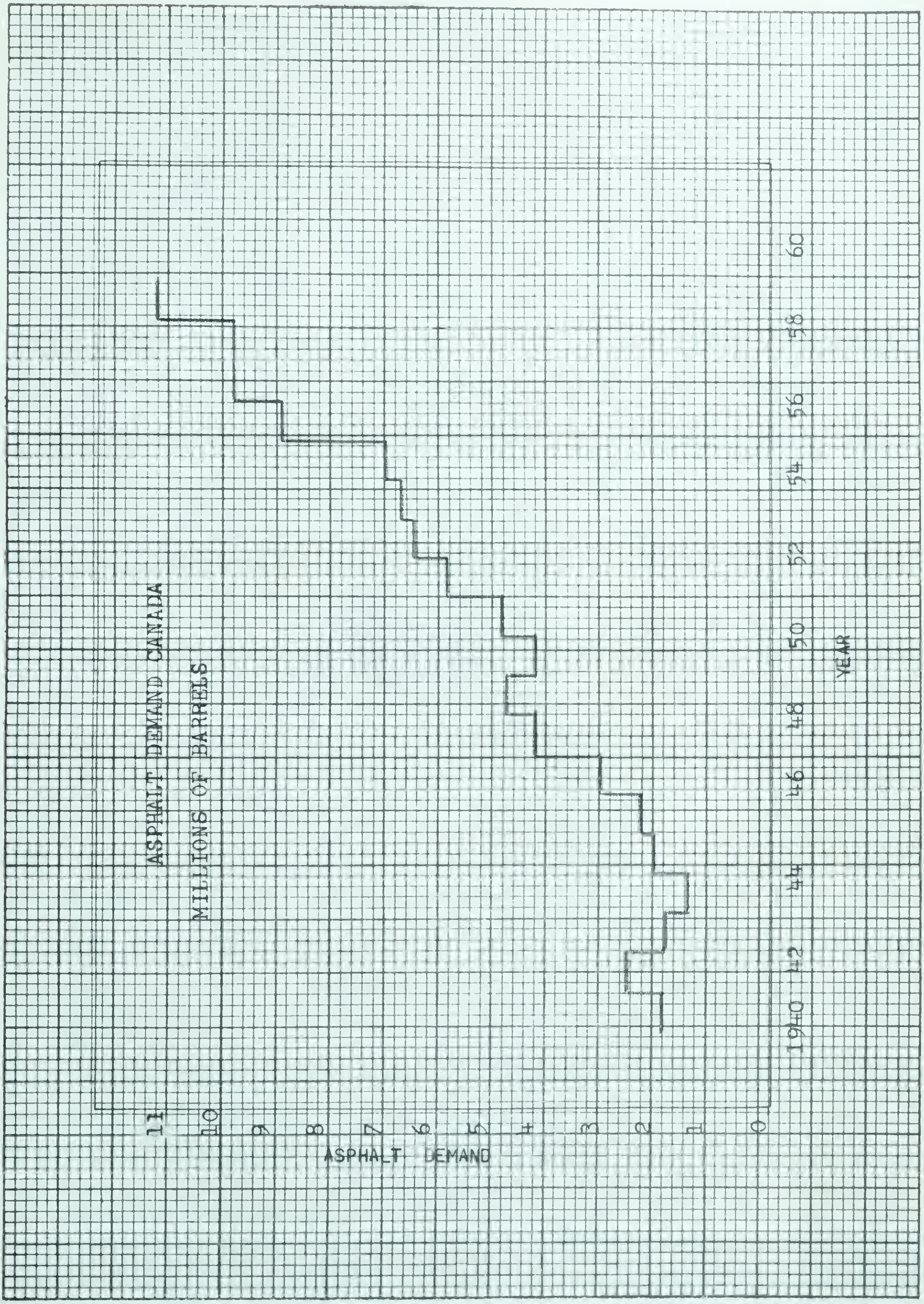

ASPHALT DEMAND CANADA
MILLIONS OF BARRELS
YEAR
1940
42
44
46
48
50
52
54
56
58
60
0
1
2
3
4
5
6
7
8
9
10
11
ASPHALT DEMAND

FIGURE 1

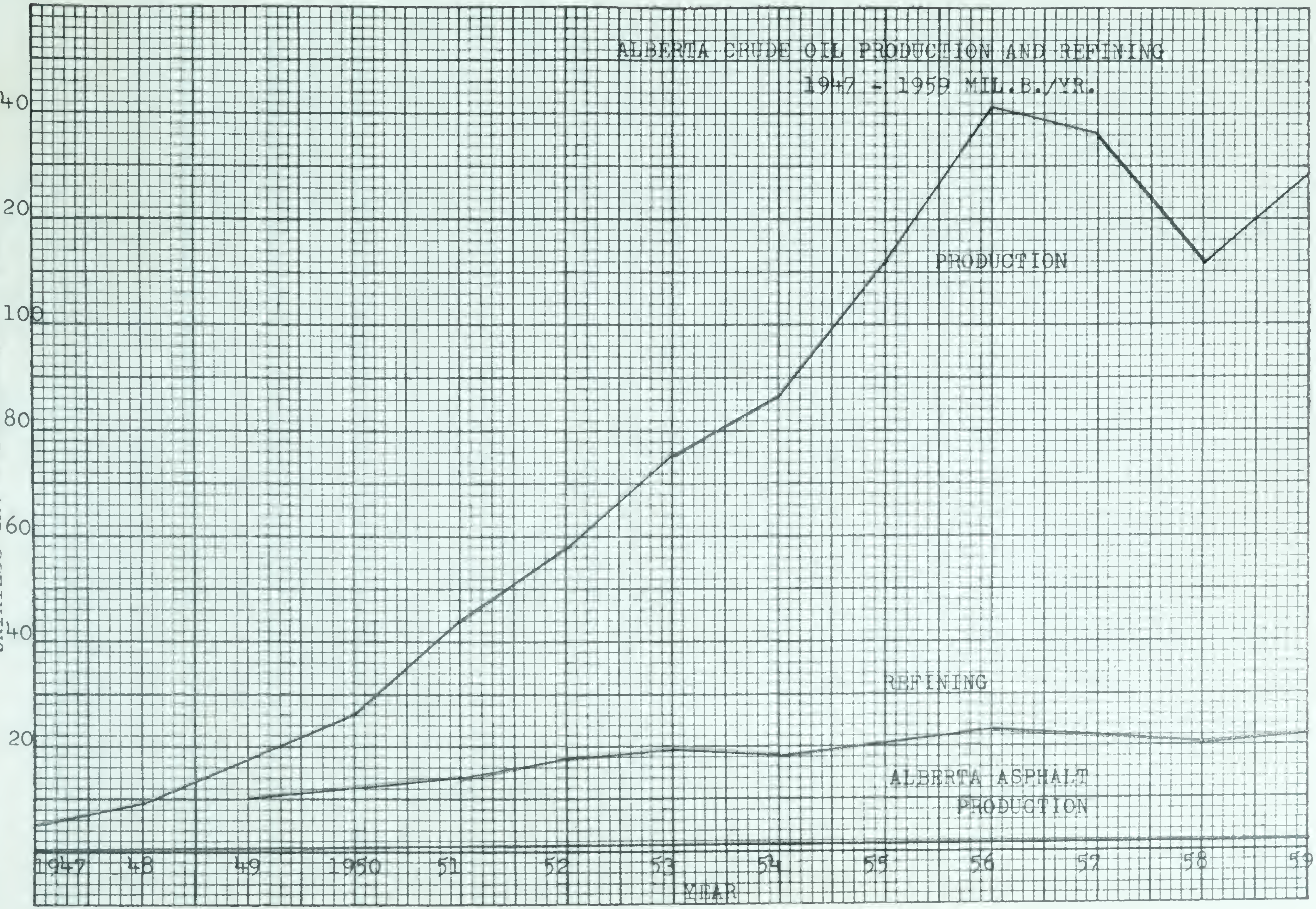

ALBERTA CRUDE OIL PRODUCTION AND REFINING
1947 - 1959 MIL.B./YR.
PRODUCTION
REFINING
ALBERTA ASPHALT
PRODUCTION
40
20
100
80
60
40
20
1947
48
49
1950
51
52
53
54
55
56
57
58
59
YEAR
CRUDE OIL PRODUCTION AND REFINING

FIGURE 2

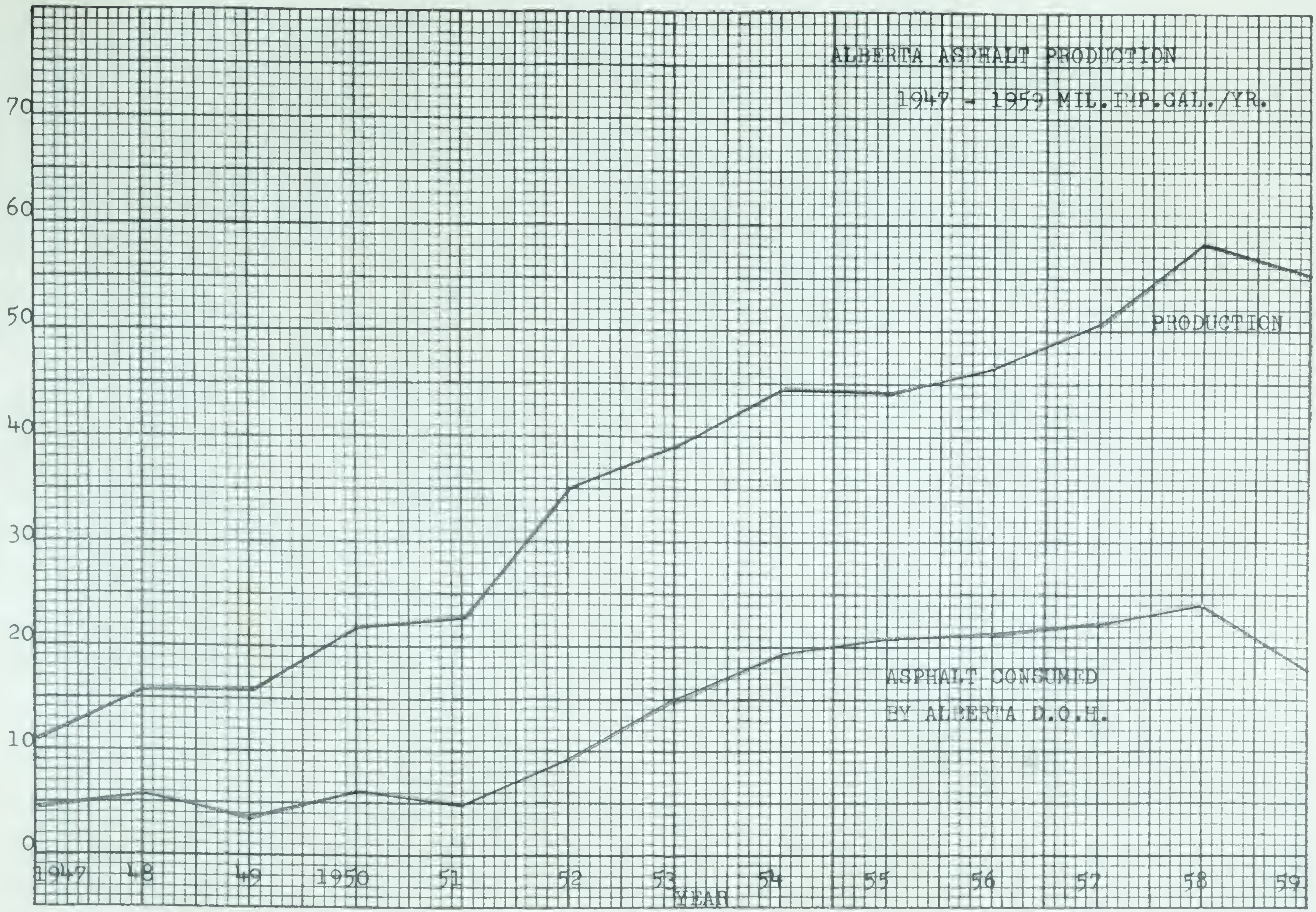
year in 1956. From early 1957 and on into 1958 there was a general decline in production. This was due to the market for Alberta crudes in the Pacific Northwest being temporarily lost and the oil produced in Saskatchewan displacing some Alberta crude in the eastern market areas.[4]

From 1958 to 1959 there was an increase of some nine million barrels per year, so the indication is that Alberta is gradually regaining some of its lost oil market.

Figure 2 also shows that the refining capacity in Alberta over the last few years has remained relatively constant. The line representing the refining capacity will gradually slope upward with the addition of more refineries to the provinces. At the extreme bottom of Figure 2 is plotted the Alberta asphalt production figures in millions of barrels per year over the years 1947 to 1959. It is seen that asphalt production accounts for approximately 8 to 9 per cent of the total products derived from refining. The other products would be gasoline, kerosene, diesel fuel and motor oil.

Figure 3 shows the production of asphalt in Alberta from 1947 to 1959. There has been a steady increase of approximately 3.5 million gallons per year (one barrel equivalent to 35 gallons). As an illustrated example of asphalt consumption in the province the figures from the Alberta Department of Highways were used.[5] Their consumption figures of total asphalt used closely paralleled the production line graph in Figure 3. Other major consumers of Alberta asphalt would be The Department of Transport, Public Works Departments for major cities and towns plus the many construction companies located in Alberta.

[4]Report of the Deputy Minister, Dept. Mines and Minerals, 1959.



ALBERTA ASPHALT PRODUCTION

FIGURE 3

4. HIGHWAYS IN ALBERTA

Table II shows the total number of miles of main, secondary, district and local roads. It should be noted that 65.8 per cent of the main highways are paved but taking the overall percentage of all classes of roads paved the answer is a meager 6.6 per cent.(3)*

The figures in Table II do not include the number of miles of concrete roads in Alberta. At the time these figures were released the only concrete road in existence was the short test road incorporated into No. 2 Highway just north of Calgary.

*See 1959 edition.

TABLE II

ALBERTA HIGHWAY FIGURES

IN MILES

	Concrete	Bituminous	Gravel & Stone	Total Surfaced	% Surface Paved
Main Roads		2505.3	1,300.6	3,805.9	65.8
Secondary Roads		200.0	1,656.6	1,856.6	16.1
District and Local Roads		52.8	35,522.6	35,605.4	0.1
Total		2758.1	38,509.8	41,267.9	6.6

CHAPTER III

MAJOR PROBLEMS ASSOCIATED WITH ASPHALT IN A BITUMINOUS PAVEMENT

When considering a bituminous pavement, the percentage amount of asphalt per unit weight of mix is in the neighborhood of 5 per cent. Therefore, it would seem that the quality of the asphalt would not be a principal problem in asphalt surfacing. In a bituminous pavement that has failed, it would only be reasonable to place the blame on the asphalt if correct design procedures and construction methods were employed, for example the aggregate should be of a sound and durable nature, the grading selection should be based upon the load the pavement will carry, and lastly the asphalt percentage should be based upon trial mix design methods. This is rarely the case although the remaining portion of this chapter will deal with the exception, the case where the asphalt was responsible and what inherent factors in or associated with the asphalt caused the failure.

The failure of a bituminous pavement due to low quality asphalt may fall under two separate headings. The failure may be either a structural failure or a functional failure. The structural failure is a collapse of the pavement structure or one or more of the pavement

components to such an extent as to make the pavement incapable of sustaining the loads imposed upon its surface. The functional failure may or may not be accompanied by a structural failure but it is such that the pavement will not carry out its intended function without causing discomfort to the motorist or without causing high stresses in the plane or vehicle which passes over it due to its roughness.[6]

The failures discussed in this chapter due to low quality asphalt being used in a bituminous mix are of a functional nature which may extend themselves to a structural failure if maintenance steps are not taken early in the development stage.

1. HARDENING OF THE ASPHALT

Hardening of an asphalt cement is a function of temperature and time. The relationship between hardness and temperature varies linearly on a semi-log plot. In other words the lower the temperature the harder the asphalt, for example at $0^{o}F$ asphalt would be very stiff while at $200^{o}F$ it possesses the properties of a semi-viscous fluid.

Through the passage of time an asphalt cement will harden more significantly due to its continual subjection to the elements than due to time-consuming reactions inherent in the asphalt itself.

If the asphalt cement in a road surface hardens quickly, cracking, raveling and other signs of pavement deterioration can usually be observed during its early life.[7] The asphalt may undergo this hardening process during mixing, placing or later during its service life. These three stages the asphalt passes through will result in hardening due to changes in temperature and/or changes in composition.

Mixing Stage. When the asphalt is being mixed with the preheated aggregate hardening may occur due to either overheating or to an over extended heating period, although the latter is not as prevalent as the former.

Overheating as specified by today's paving manuals is any mixing temperature in excess of 325°F. The detrimental effect of having a mixing temperature in the neighborhood of 325°F is not so much overheating but rather that the film of asphalt coating the aggregate is much too thin. If mixing temperatures were based upon the asphalt's temperature-viscosity characteristics then the film thickness would be greater and the resulting mix would possess more strength.

The next significant factors that tend to harden the asphalt during the mixing cycle are oxidation and volatilization.[10] Oxidation is the chemical attack of air on the asphalt while volatilization is the evaporation of the lower molecular weight hydrocarbons. The respective rates of each are a function of the exposed asphalt surface area and are notably increased due to an increase in temperature. Therefore a marked amount of oxidation would take place during the mixing cycle where the exposed surface area and mixing temperature are quite high.

Overheating is evidenced more during the fall and late fall seasons when paving takes place in air temperatures at or below 40°F. This may seem necessary from the contractor's point of view because the asphalt mix must arrive on the job at a temperature that will allow placing and compacting to be carried on in their usual manner.

Placing Stage. During this stage of the asphalt's life the fore-mentioned effects of oxidation and volatilization are still witnessed, but at a reduced rate. Means to combat these effects are exemplified in mix design practice where the percent air voids, although controlled by the asphalt's tendency to "flush" are maintained at an acceptable minimum. Once the asphalt pavement has been laid and compacted, another method, although expensive, to reduce the rates of oxidation and volatilization is by the application of a seal coat.[8]

Service Life. During the service life of a bituminous pavement, oxidation and volatilization are continually resulting in hardening of the asphalt, although at a still lessened rate. Minor sources of hardening during this time are accomplished by the action of light[10] and by the formation of an internal gel-like structure.[7]

The detrimental effects of sunlight sometimes occur when the actinic rays or the green, blue and ultra-violet rays of the sun decompose the asphalt into water molecules and water soluble molecules. This process is called photo-oxidation. The other fore-mentioned minor source of hardening, sometimes known as thixotropic hardening, can be observed on deadend streets or streets that carry a small amount of traffic. On these streets the pavement tends to crack. This is due to an arrangement of the molecules in the asphalt to form a gel-like structure. The length of time this process lasts is a few hours and is considered negligible in a year.

The only redeeming feature of this detrimental effect is that the process is reversible and can be reversed by physical working or heating.

2. STRIPPING OF ASPHALT

The other major source of trouble, but not always derived from low quality asphalt, is the problem caused by stripping.(11) Stripping is any process that causes a separation between the asphalt and the aggregate in a bituminous mix. In a hot or cold mix operation the major portion of the stripping results from two sources. They are the action of water on a bituminous mix, and the surface characteristics of the aggregate used in the mix. The main qualification of the asphalt is such that it must possess adhesion tensions in order to bind it to the aggregate. These adhesion tensions are affected by the migration of asphalt molecules and their preferential concentration at the surface.(11)

The qualities of the aggregate necessary to reduce stripping are:

1. The aggregate should be dense as opposed to being porous. This is based on the assumption that the drying cycle does not remove all the pore water from the aggregate. If this were true then the denser the aggregate was the less chance there would be of "bubbling" occurring during the placing stage. Bubbling is the release of moisture in the form of steam, from the aggregate during the placing stage of a bituminous mix. If the initial assumption made was not true, then, the more porous the aggregate the greater would be the bond between the asphalt and the aggregate. This would then lend itself to an increased amount of asphalt that would have to be used.
2. The drying cycle of the aggregate should remove all surface moisture.

Surface moisture is usually all removed from the aggregate regardless of the aggregate's initial moisture content. This is achieved by maintaining control of the length of the drying cycle and the temperature used in the cycle. Removal of pore-water during the drying cycle is usually incomplete because of the production demand during the summer months being very high. This statement bears out the assumption made under the subheading No. 1.

3. The aggregate should be hydrophobic as opposed to hydrophilic. These two words, "hydrophobic" and "hydrophilic" define the surface characteristics of the aggregate.

   Hydrophobic - the aggregate has a definite repulsion for water due to the surface forces on the aggregate.

   Hydrophilic - the aggregate has a preferential affinity for the water molecule.

Since these definitions are reasons in themselves why one type of aggregate should be used over another no more need be said on the subject.

In a cold mix operation drying of the aggregate is omitted; therefore additives are employed to reduce the action of the water on the mix. This is done by chemically changing the surface characteristics of the aggregate asphalt, thus permitting the asphalt to return to the aggregate after being initially displaced by the water.[12]

CHAPTER IV

THE SIGNIFICANCE OF PRESENT DAY ASPHALT SPECIFICATIONS AND TESTS

Standard test procedures for use in controlling the uniformity, identification and quality of asphalt cements are well established. The test procedures of the American Society of Testing Materials (A.S.T.M.) and the American Association of State Highway Officials (A.A.S.H.O.) are in use in all parts of the United States. In addition various local agencies which use asphalts employ other test procedures. Within the last ten years very few changes, with the exception of the 1960 edition of The Asphalt Institute Specifications, have been made in the test procedures or in the tests specification control of the asphalt cements. The asphalt technologists are not completely satisfied with the present test procedures and specifications; but there are considerable differences in opinion as to what changes should be made in order that more uniform and better quality materials at reasonable prices will be insured by the test procedures and specifications.[8] It has been observed throughout the history of asphalt specifications that more attention was paid to the writing of tests for identification and inherent physical properties, rather than for the measurement of quality. On the other hand at least some of such tests are

[8]Brown, Marshall and Benson, Fred J., p. 1.

needed to prevent the use of asphalts from sources of known inferiority and refined by questionable methods.[7]

1. THE PURPOSE FOR SPECIFICATIONS

The reason we use asphalt specifications are for

1. Bidding purpose;
2. Quality control;
3. Uniformity of product.[13]

Specifications are essential to competitive bidding because these place limitations on the quality or physical characteristics of the asphalt in question. If it were not for these limitations, a tendered price on asphalt could be submitted that would be far below the normal bidding price.

In order to attain competitive bidding with regard to quality a lower limit or in other words a minimum acceptable value of quality is specified so the bidding price will correspond to any previous estimates made. Through the difficulty in defining quality with regard to asphalt, this discussion will only lend itself to the various degrees of quality asphalt may possess as measured on a comparative basis by the results of the testing program.

Figure 4 illustrates the relationship between the quality of asphalt maintained by a supplier and the minimum acceptable quality that may sometimes be specified. Since asphalt quality is rather a nebulus quantity the ordinate of Figure 4 will have no units but will increase as the arrow indicates. Nos. 1 and 6 are of the highest quality while Nos.

[7]McLeod, N. W., p. 141.

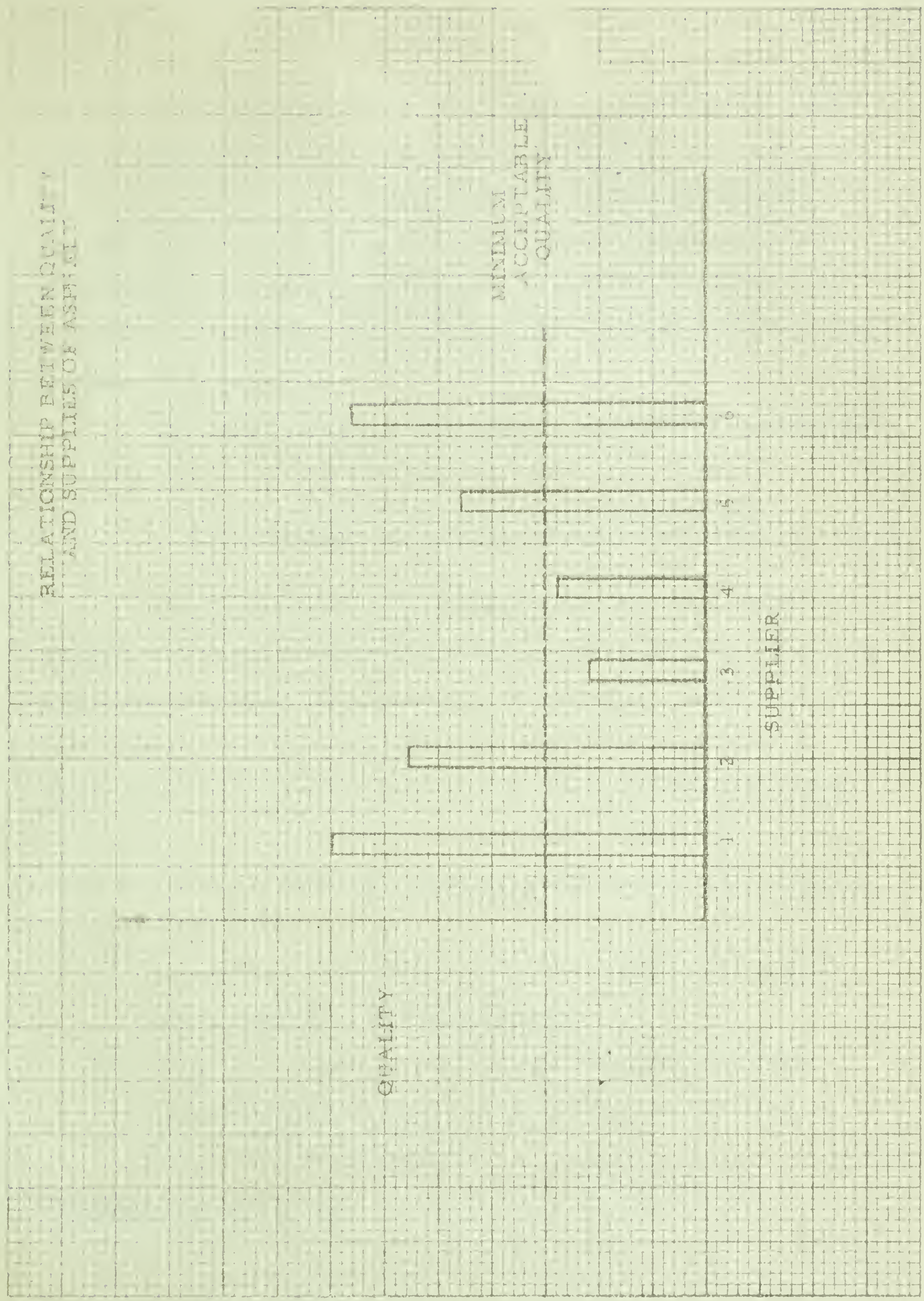

RELATIONSHIP BETWEEN QUALITY
AND SUPPLIES OF ASPHALT
MINIMUM
ACCEPTABLE
QUALITY
QUALITY
SUPPLIER
1
2
3
4
5
6

FIGURE 4

3 and 4 are of the lowest quality. The minimum acceptable value will exclude suppliers 3 and 4 but will include anything above this quality. One of the properties of the American Society for Testing Materials' specifications is that it operates on a minimum acceptable basis when their specifications have been selected by an agency to control the use of a product on a project. The numbers used in this analogy do not apply to Alberta Oil Refineries.

With regard to uniformity of products specifications control the range through which a material may vary in one of its properties.

2. THE CONTROL OF ASPHALT QUALITY BY SPECIFICATIONS

In the introduction of this chapter the question was raised as to whether or not today's asphalt specifications measured quality or did they only serve as a means for identification of the asphalt. In order to discuss whether or not these specifications do measure asphalt quality, closer consideration must be given to what characteristics are desired in an asphalt cement intended for a road cement. The asphalt cement might be reasonably expected to satisfy the following six basic engineering requirements.[7]

1. It should have the consistency needed to enable it to function satisfactorily as a cementing material.
2. It should not harden or undergo either physical or chemical changes during the lifetime of the pavement to such a degree that the surface deteriorates.

[7] McLeod, N. W., p. 144.

3. During the life of the asphalt surface, the asphalt cement should possess and retain good affinity or adhesion.
4. Asphalt cements manufactured from petroleum should be almost entirely soluble in carbon disulphide or carbon tetrachloride.
5. The asphalt cement should be safe as possible to handle at the highest temperature to which it will be subjected during construction and maintenance operations.
6. An engineer has the right to expect that the asphalt cement supplied will be uniform in its characteristics.

3. SPECIFICATION TESTS AND THEIR SIGNIFICANCE

In March, 1960 the Asphalt Institute published a revised edition of their 1947 asphalt specifications. Table III lists the specifications from both years applicable to 120 - 150 and 200 - 300 penetration grade asphalts. This revision incorporated two more tests, the thin film oven test and the saybolt furol viscosity test at 275°F. These additions are the initiating of further modifications of asphalt specifications that may come in the not too distant future.

With regard to significance of tests, one of the most specified tests (although not that significant) is the standard penetration test.(8)* This test is for identification purposes only, but modifications of it employing a ratio of different penetrations at different temperatures give an indication of the asphalt's temperature susceptibility characteristics. An example of this is the susceptibility factor.

*McLeod, p. 9.

TABLE III

ASPHALT SPECIFICATIONS - 1947 AND 1960

	1960		1947	
Penetration 77°F, 100 gm., 5 sec.	120-150	200-300	120-150	200-300
Viscosity at 275°F.				
Saybolt Furol S.S.F.	70+	50+	-	-
Kinemetic Centistokes	140+	100+	-	-
Flash point (Cleveland Open Cup)°F	425+	350+	425+	350+
Thin film oven test				
Penetration after test 77°F. 100 gm., 5 sec. % of original	42+	37+	-	-
Loss on heating 325°F., 5 hrs. %	-	-	2-	2-
Penetration after loss on heating 77°F., 100 gms., 5 sec. % of original	-	-	70+	60+
Ductility				
at 77°F cms	60+	-	60+	-
at 60°F cms	-	60+	-	60+
Solubility in carbon tetrachloride %	99.5+	99.5+	99.5+	99.5+

General requirements: The asphalt shall be prepared by the refining of petroleum. It shall be uniform in character and shall not foam when heated to 350°F.

$$\text{susceptibility factor} = \frac{\text{penetration } 77^{\circ}\text{F} \quad 100 \text{ g} \quad 5 \text{ sec}}{\text{penetration } 32^{\circ}\text{F} \quad 200 \text{ g} \quad 60 \text{ sec}}$$

This factor and many like it (8)* are very controversial in nature because of the different weights and times involved. One official summed it up in the following words,

> "How futile it is to try and extract a meaning from such factors as the difference between the penetration at 115°F and 32°F divided by the penetration at 77°F when each is measured with different weights and temperatures."(15)

Of course there are factors which utilize the same weights and times but these are only applicable to a very low penetration grade asphalt.

As was mentioned in earlier chapters, an asphalt will harden during its service life. The penetration test has been used to measure this hardening. The actual significance of this application of the test is as controversial as the test's measurement of temperature susceptibility when used, for instance, in the penetration ratio. Dr. Olienses, a noted authority in the field had the following to say about this subject,

> "In mid-winter, the temperature may drop far below 32°F or 0°F and even lower. Have you ever tried to see what the consistency of paving asphalt is at 0°F? Suppose you take a sample of paving cement - any paving cement, good, bad, or indifferent - pour it out in a layer one-eighth to one-sixteenth inch thick and chill it to 0°F. When so chilled the sheet of asphalt will splinter like glass; it retains not a vestige of ductility; and yet we know that many pavements have gone through zero weather without cracking - and their penetration at that temperature must be many times harder than zero. Gentlemen, that thought simply stops you in your tracks when you try to

*McLeod, p. 24.

(15)Domoulin, A. W. and Izatt, J. O.

establish the existence of some connection between the pure penetration of asphalt and the cracking tendency of pavement."[7]

The Saybolt Furol Viscosity test at 275°F is very significant in a practical sense because its results are applied directly to mixing plant operations. The results supplied in the form of a viscosity-temperature chart will give the correct temperatures that may be used for mixing, spraying and pumping for any particular grade and source of asphalt cement. The slope of the viscosity-temperature line will indicate whether the asphalt is greatly susceptible to temperature change or not.

The flash point test as specified by A.A.S.H.O. or A.S.T.M. can be either measured by the Cleveland Open Cup method or the Pensky-Martens method. Although each method is acceptable the results from the Pensky-Martens test are lower than the results obtained from the Cleveland Open Cup method. This is due to two reasons. First, the Pensky-Martens test procedure employs a closed test container so that an accumulation of volatile gases will build up thus lowering flash point and secondly, this procedure makes use of a stirring apparatus so a scum will not develop on the surface of the asphalt cement. The development of this scum would cause an increase in the flash point. The significance of this test is that it is merely a safety test. It indicates the maximum temperature to which an asphalt may be heated without the danger of ignition[8]*

[7]Brown, M., and Benson, F. J., p. 13.

*McLeod, p. 39.

The thin film oven test measures the loss or gain in weight of an asphalt due to oxidation and volatilization. This part of the test is used as a check in contamination that may have occurred during handling or shipping. If handling and shipping procedures have been correctly adhered to the asphalt tested rarely fails this portion of the test.

From the penetration test performed on the residue an indication of the degree of hardening can be shown. This degree of hardening is expressed in the form of a ratio.

$$\text{Percent of original penetration} = \frac{P_2}{P_1} \times 100$$

where

P_2 = penetration after the test

P_1 = penetration before the test

The lower the percent of original penetration the higher the degree of hardening and vice versa.

The fore-runner of this test, the loss on heat test and penetration of the residue, was discarded primarily due to the fact that the specific areas involved between this test and the asphalt during plant mixing operations were so vastly different. Specific area is the ratio of the total surface area to the total volume. To rectify this the thin film oven test was incorporated. Although the thin film oven test is supposed to simulate plant mixing conditions there is one disadvantage. This disadvantage is that the degree of hardening measured is applicable only to the test and its correlation to the degree of hardening that occurs during mixing operations is very limited;[16] although the Bureau

of Public Roads showed very good correlation between their figures. Consequently, until additional information has been obtained concerning this correlation care should be taken to avoid unreasonable specification limits for the permissible loss in penetration at 77°F of the residue.(7)*

Ductility requirements are almost universally used in the specifications for semi-solid asphaltic materials of all types. It is generally considered that asphalts possessing high ductilities have good cementing qualities in the road surface and adhere well to aggregates. In recent years the tendency in the specifications has been to increase the requirement for ductility. There are, however, many asphalt technologists who are of the opinion that the ductility test has little value.(8) Correlation of the test procedure to any action which may take place in the road surface is poor.

In the test the material is tested in mass while in the pavements it exists in thin films. Very little is known of the actual stresses which exist in the asphalt films in a pavement, but it is difficult to conceive that a rate of pull of five centimeters per minute at a temperature of 77°F are representative of any condition of stress and strain that might exist in the field. Although the correlation of the results to field performance is poor some information can be gained from the test. For instance, a very high ductility is associated with asphalts having poor temperature-susceptibility characteristics, that is, a small change in temperature would result in a large change in the viscosity of the asphalt. The extreme would be where the line depicting the asphalts rheologic properties on a temperature viscosity becomes nearly vertical. The ductility varies with the source

of crude oil and the method of processing. Blown asphalts have low ductilities and natural weathering produces a decrease in ductility.(8)*

If failure did occur with regard to the solubility in carbon tetrachloride test, it would be due to either a high carbene content, which is a measure of the care used in refining, or a large amount of foreign matter, for example, sand or salt. To determine what caused the failure the test would be performed again using carbon disulphide instead of carbon tetrachloride as the solvent. Since carbenes are soluble in carbon disulphide the only necessary check would be on the amount of foreign matter present. Some believe the solubility is of little value, however, relaxing or discontinuing this requirement would probably lead to relaxing of desalting and other refinery operations necessary to remove the impurities with a resultant decrease in quality.(8)**

The softening point, although not usually specified in asphalt cement specifications as a measure of consistency has been used as a method for determining the temperature susceptibility characteristics of asphalt by means of the penetration index. This index is related to the softening point temperature and standard penetration value by a nomograph.(17)

The specific gravity usually gives results in a range from 0.98 to 1.04 for petroleum refined asphalt. Its significance is limited from a specification standpoint but is very important when used in mix design practice. It has been recommended that it should not be included in specifications because it would only impose a limitation of the asphalt

*McLeod, p. 55.

**McLeod, p. 25.

used in construction. Instead, every specification for asphalt cement should include a statement making it mandatory for the asphalt supplier to furnish the user with the actual value of the specific gravity 77/77 F of the asphalt cement being provided.(7)*

The spot test was not in the testing program because the significance of its results can be obtained from the thin film oven test and the solubility test. The main function of the spot test is to measure the degree of heterogeneity or homogenity of asphalt. The point of principal interest is the measure of heterogenity caused by overheating or cracking. Although there is much controversy as to its measure of asphalt quality, it is being used by thirty-six out of approximately fifty agencies in the United Statesand Canada.(8)

4. THE EFFECT OF REFINING PROCESSES ON THE COMPOSITION OF ASPHALT

Associated with all oil refineries are a number of definite processes each of which is pertinent to the production of a definite product. Only those processes which are used in asphalt production will be discussed. These processes are:

1. Atmospheric distillation,
2. Vacuum distillation,
3. Steam distillation,
4. Oxidation.

*Brown and Benson, p. 156.

The first three processes are similar in the fact that the crude oil is heated and as the temperature rises the various constituents of the oil are set free. In atmospheric distillation the vapors which are evaporated are condensed at the various levels in the fractionating tower.[18] Those with the highest boiling points are condensed near the bottom of the tower. The main disadvantage of this process is the high temperatures involved.[8]* A high temperature will be regarded as one greater than 750°F. These temperatures give rise to more oxidation and volatilization than is found in the vacuum and steam distillation processes. In these processes the application of steam or the introduction of a vacuum will lower the petroleum's boiling point thus minimizing the amount of decomposition that might take place.[19] The reason oxidation is a necessary refining process is because some crude stock being refined may vary between a semi-asphaltic to a non-asphaltic crude petroleum oil. If it were not for the oxidation or air blowing process the asphaltic materials would not be acceptable for road making purposes.

The actual air blowing process is accomplished by bubbling air through the liquid asphalt.[8]** The reaction that is carried on is the conversion of the reactive aromatic oils to asphaltenes. This conversion, with reference to Chapter V, produces an asphalt that is less temperature susceptible but possesses less ductility than a non-blown asphalt.[20] The detrimental effects of air-blowing to the asphalt is that an increase in the carbene content is witnessed.[19] The effects of the high carbene content will be discussed in Chapter V.

*McLeod, p. 25.

**McLeod, p. 2.

CHAPTER V

ASPHALT COMPOSITION

Since asphalt is a derivative of petroleum, the properties of the asphalt will be a function of the type of petroleum; therefore, prior to any discussion on asphalt composition, a closer look must be taken at the parent material.[21]

1. CRUDE OIL CHARACTERISTICS

Crude oil is a complex combination of constituents varying from gasoline to a heavy asphaltic residue. Since these constituents vary in amount, systems have been devised so that crude oil can be classified. The following three systems classify with respect to API gravity, composition and description, respectively.[21]*

API (American Petroleum Institute) gravity is an expression of a specific gravity test. The results of this test are converted to API degrees by means of a simple equation. Although the API gravity system is the only one that has definite limits dividing the various types of crude oil there is a correlation between this system and the other two; for example, a crude oil with an API gravity greater than 40° would be

*See Vol. XXI, p. 695.

paraffinic in nature and described as a light crude oil.

API Gravity	Composition	Description
40^{o} API	Paraffinic	Light
$33.1 - 39.9^{o}$ API	Intermediate	Medium
33.0 API	Napthenic	Heavy

Figure 5 shows graphically the three classification systems. The API gravity system was used to show the delineation between the various types of crude oil. As a crude rule of thumb it has been stated that the lower the API gravity the higher the percent asphalt yield will be.[10]

In some reference texts the fore-mentioned classification system is not used. All that is mentioned with regard to crude oil variations is that they vary between

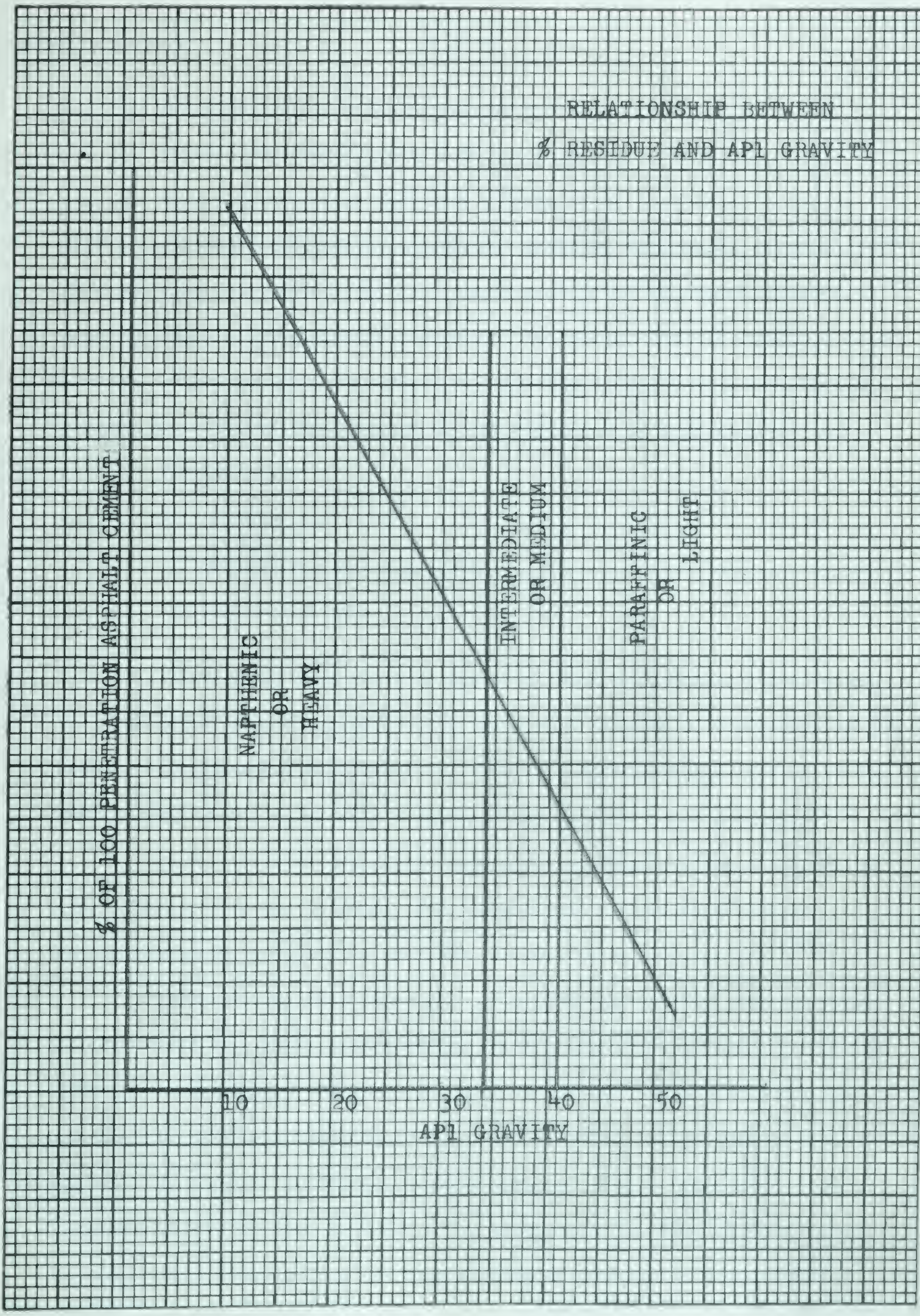
1. open chain hydrocarbons and
2. cyclic hydrocarbons of the ring type[19]

Thesea re essentially paraffinic and napthenic base crude oils respectively.

2. BASIC COMPOSITION OF ASPHALT

Since asphalt is such a complex material due to the wide range in molecular weight of its components, there has been many methods used for determining its composition. The following, or what will be known as the general composition of asphalt, will be used throughout this report.

Asphalt is considered a collodial suspension of the following,[22]



RELATIONSHIP BETWEEN
% RESIDUE AND API GRAVITY
% OF 100 PENETRATION ASPHALT CEMENT
NAPTHENIC OR HEAVY
INTERMEDIATE OR MEDIUM
PARAFFINIC OR LIGHT
10
20
30
40
50
API GRAVITY

FIGURE 5

1. Asphaltenes (molecular weight 900+),
2. Resins (molecular weight 540 - 900),
3. Oils (molecular weight 370 - 710),

plus an additional component, carbene, which is essentially graphite.[10] This general composition differs from some of the classical methods of determining the composition of asphalt, due to the various means of separation. For example, by means of solvent precipitation and chromatographic separation, the composition of asphalt is as follows:[20]

1. Asphaltenes
2. Petrolenes
   (a) Paraffines and napthenes
   (b) Aromatic oils

When using hydrocarbon solvents, such as pentane and propane the separation of the constituents is done with respect to molecular weight rather than chemical composition. This is a disadvantage because of the overlapping of the molecular weights of the asphalt's components.[23]

In the Traxler-Schewyer separation method, a two-step solvent extraction procedure is used. The butanol extraction produces the asphaltics while the acetone extracts the saturates and cyclics.[24]

These three mentioned procedures in determining asphalt composition have one basic disadvantage, that is they are not able to tell the differences in asphalts because the high molecular weight material is not the controlling factor. It is the low molecular weight material associated with the high molecular weight material that is important. An example of this is cited by Schweyer, reference No. 24. In this report a comparison was made of the engineering properties of two asphalts

with the same asphaltene content. Accordance was found only in the standard penetration test, the other results differed markedly through a varied testing program. This example shows the action of composition on the properties of an asphalt.

The causes of these changes in properties will be discussed with regard to the general composition of asphalt.

Characteristics of Components. The characteristics of the four components as cited in the general composition of asphalt are as listed.

Asphaltenes: These high molecular weight hydrocarbons form the body of the asphalt. They effect the penetration properties of the asphalt plus giving it its black to brown color. The percentage of asphaltenes can be found by extraction, using selective solvents.

Resins: These medium molecular weight hydrocarbons are referred to as the peptizing agent. They impart the adhesion and ductile properties to the asphalt.

Oils: These low molecular weight hydrocarbons impart the rheologic properties to the asphalt plus also having an effect on its ductile properties.

Carbenes: These relatively small particules are essentially graphite and are soluble in carbon disulphide and insoluble in carbon tetrachloride. They are usually present in a small percentage in straight-run asphalt. Thermal cracking will increase this percentage markedly. One percent is the division point between a straight-run asphalt and a cracked asphalt; the cracked asphalt usually having a carbene content greater than the one percent. This percentage can then be classified as an indicator that

reveals the amount of overheating that has taken place.

Molecular Structure. With regard to the molecular structure of the asphalt there are three types of hydrocarbons present.[25] These are:

1. Saturated hydrocarbons,
2. Unsaturated hydrocarbons,
3. Aromatic hydrocarbons.

The saturated hydrocarbons are stable due to their single bonds between carbon atoms. They form a chain type molecule and are found in rubber, wax and paraffin. The unsaturated hydrocarbons are unstable due to double and triple bonds between carbon atoms. There are two series of unsaturated hydrocarbons.

1. Alkenes - anything with a double bond;
2. Alicyclics - ring consists only of carbon.

The alkenes are recognized by their double valence bonds between carbon atoms. Their instability arises from the formation of larger molecules as a result of the bonding. The alicyclics form closed ring chain compounds and are predominately present in naphenes or napthenic crudes.

The aromatic hydrocarbons form a ring type molecule. They are found in benzene and can be recognized by their odor.

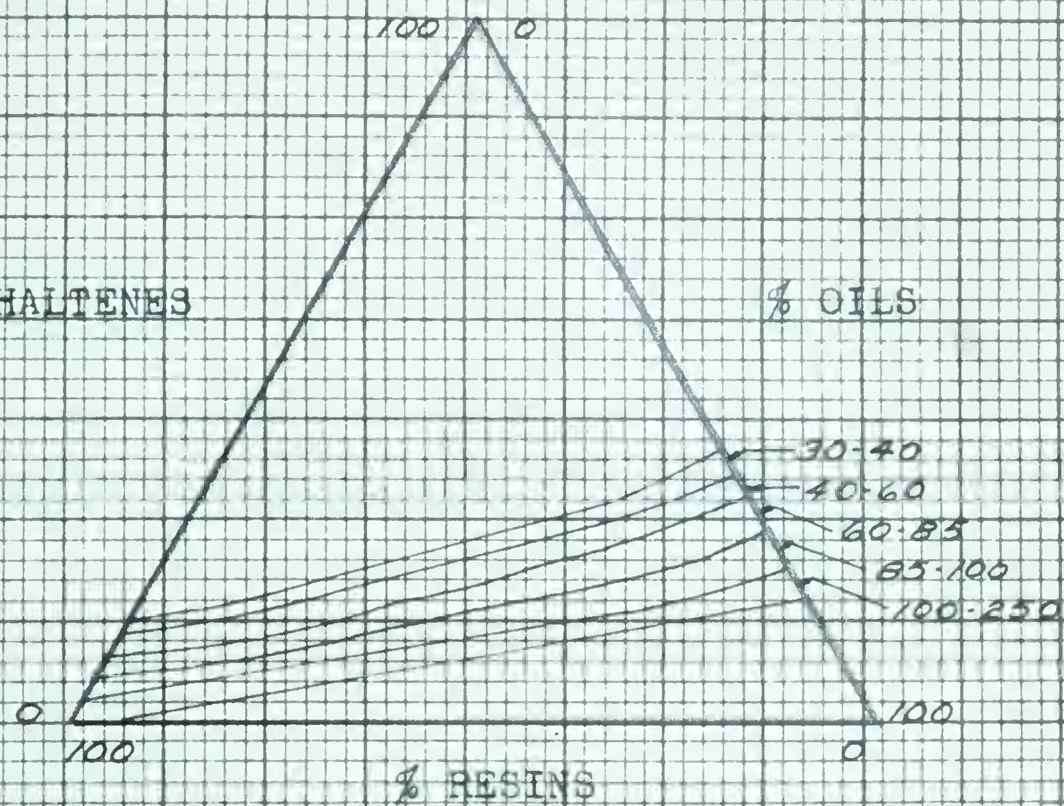
Asphalt contains all three of the above type of hydrocarbons. Since it is beyond the scope of this paper to fully discuss the molecular structure of asphalt, only the following can be said. The behavior of the asphalt will depend on the amount present of each hydrocarbon, where behavior refers to field performance qualities of the asphalt.

3. EFFECT OF COMPOSITION ON ENGINEERING PROBLEMS

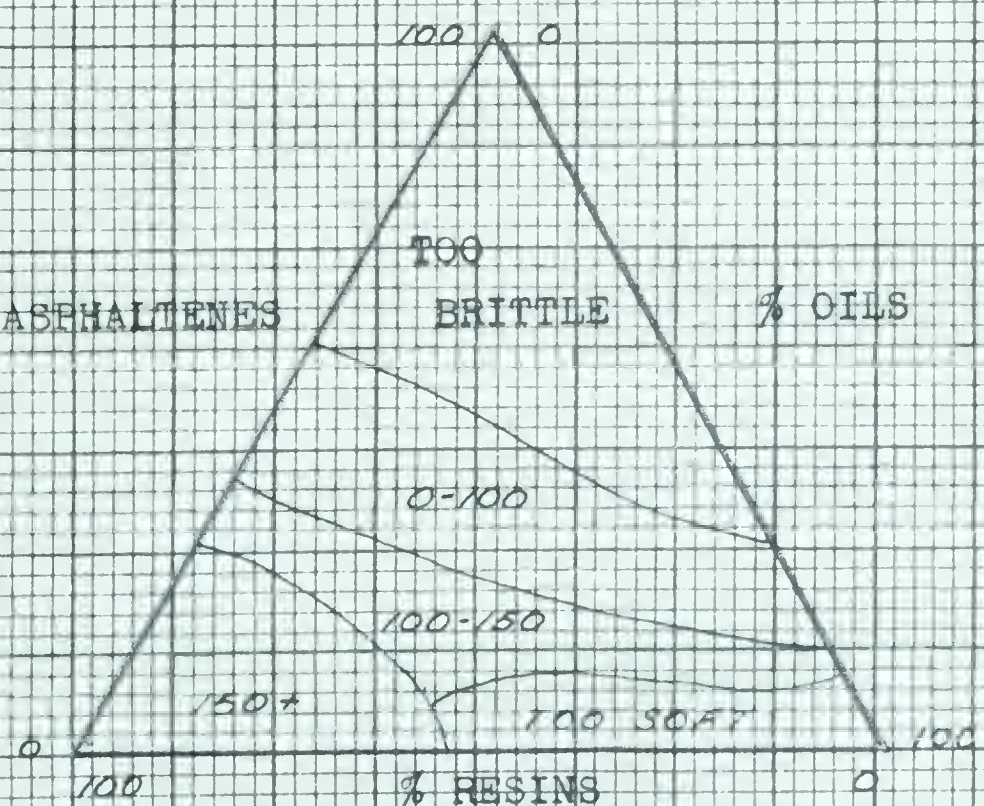
The results of recent research in asphalt composition are stressing the fact that composition will ultimately determine the quality and performance of asphalt.[26] This is paralleled to present day thinking, but along a different philosophy, where much is being done to correlate specification tests to service life.

The fore-mentioned research made reference to the changes in engineering properties with varying percentages of asphaltenes, resins and oils. From Figure 6 the variation of penetration and ductility with asphalt composition are shown. Considering Figure 6A it is seen that an increase in either the asphaltenes or the resin content will cause a decrease in penetration, with the asphaltene giving the greatest change. Figure 6B shows that the reverse is true with regard to ductility. The highest ductility occurs when the asphalt is rich in resins, but low in asphaltenes. The ductility decrease with increasing asphaltene content is more rapid the higher the oil percentage. Retrogressing slightly, any change in composition thus far discussed for a particular asphalt has been due to overheating during manufacturing or mixing operations. This would produce an undesirable product. The cause of this is due to a selective conversion of aromatic oils to asphaltenes.[20] This is similar to other results where thermal asphalts and blown asphalts were found to contain a high percentage of pentane insoluble.[27] From reference No. 23 the pentane insolubles are the same as the asphaltenes used throughout this discussion, although the nomenclature is different.

THE EFFECT OF COMPOSITION ON ENGINEERING PROPERTIES



PENETRATION VS COMPOSITION 6A



DUCTILITY VS COMPOSITION 6B

Since the asphaltenes are the only component of asphalt that affect its hardness properties the reasoning prior to this concerning asphaltene content and penetration can be readily understood.

With regard to strength tests, utilizing the Marshall and the Hveem methods, the highest values of Marshall stability and Hveem cohesion were obtained with asphalts of low ductility and a positive spot test. This would constitute a high asphaltene and oil content.

CHAPTER VI

PROPERTIES OF ALBERTA ASPHALTS

The properties of Alberta asphalts are in part dependent upon the type of crude oil used in the refining process. Referring to Chapter V experience has shown that the crude oil best suited for asphalt production varies between a medium and heavy asphaltic crude. This would include any crude oil with an API gravity of less than 39.9°. Information with regard to the refining processes, and the nature of the crude oil used by the various Alberta asphalt refiners was obtained by means of a questionnaire form. The properties of the asphalt produced by the various refineries was determined by the testing program accompanying this thesis.

1. QUESTIONNAIRE FORM RESULTS

Enclosed in Table IV are the results of a recent questionnaire form that was completed by five of the six companies in Alberta producing asphalt. The main point of the questionnaire form was to secure information with regard to:

1. What refining processes were used in the production of asphalt,
2. Nature of the crude oil,
3. What tests were performed on the finished asphalt product.

TABLE IV

QUESTIONNAIRE FORM RESULTS

	Refinery No. 1	Refinery No. 2	Refinery No. 3	Refinery No. 4	Refinery No. 5
Refining Processes used in the production of asphalt	Atmospheric & Vacuum Distillation Oxidation	Atmospheric & Vacuum Distillation Oxidation	Atmospheric, Steam & Vacuum Distillation Oxidation	Atmospheric & Vacuum Distillation Oxidation	Atmospheric, Steam & Vacuum Distillation Oxidation
Nature of the petroleum crude oil API Gravity	15.2°	22°	13° - 18°	20.5° (Average)	23.7°
Sources of crude oil	Lloydminster, Blackfoot & Lone Rock	Wainwright	Lloydminster	Taber, Conrad & Glenevis	Cessford

Refining Processes. All the refineries used atmospheric distillation, vacuum distillation and oxidation in the production of their asphalts. Variation came with the steam distillation process. Only two out of the five companies employed this method. One refinery, although it used all of the fore-mentioned processes, employed a process not mentioned in the questionnaire form.

Nature of the Crude Oil. The crude oil used for the production of asphalt in Alberta varies between the API gravity limits of 13.0° to 25.2°. Table V lists the field, pool and the API gravity of the crude oil used in asphalt production in Alberta. The fourth column of Table V is a description of the nature of crude oil as expressed in a pamphlet issued by the Department of Mines and Minerals, Province of Alberta, entitled "Alberta Oil and Gas Picture, 1947-1959."

Table VI shows the location of each of the asphalt refining companies in Alberta. Also listed are the sources of the crude oil used in the asphalt production. Figure 7 shows graphically the crude oil sources.

Tests Performed on Asphalt. Listed in Table VII are the results of question six from the questionnaire form. This table tells at a glance what refineries perform what tests on the finished asphalt product. As can be seen the number of tests listed are many and the testing program of each refinery varies markedly. The testing program of refinery number four follows the 1960 Asphalt Institute Specifications. It is of noted interest that only one other refinery performs the two new additional tests incorporated into this specification. These two new tests are the thin film oven test and the saybolt furol viscosity test at 275°F. Although

TABLE V

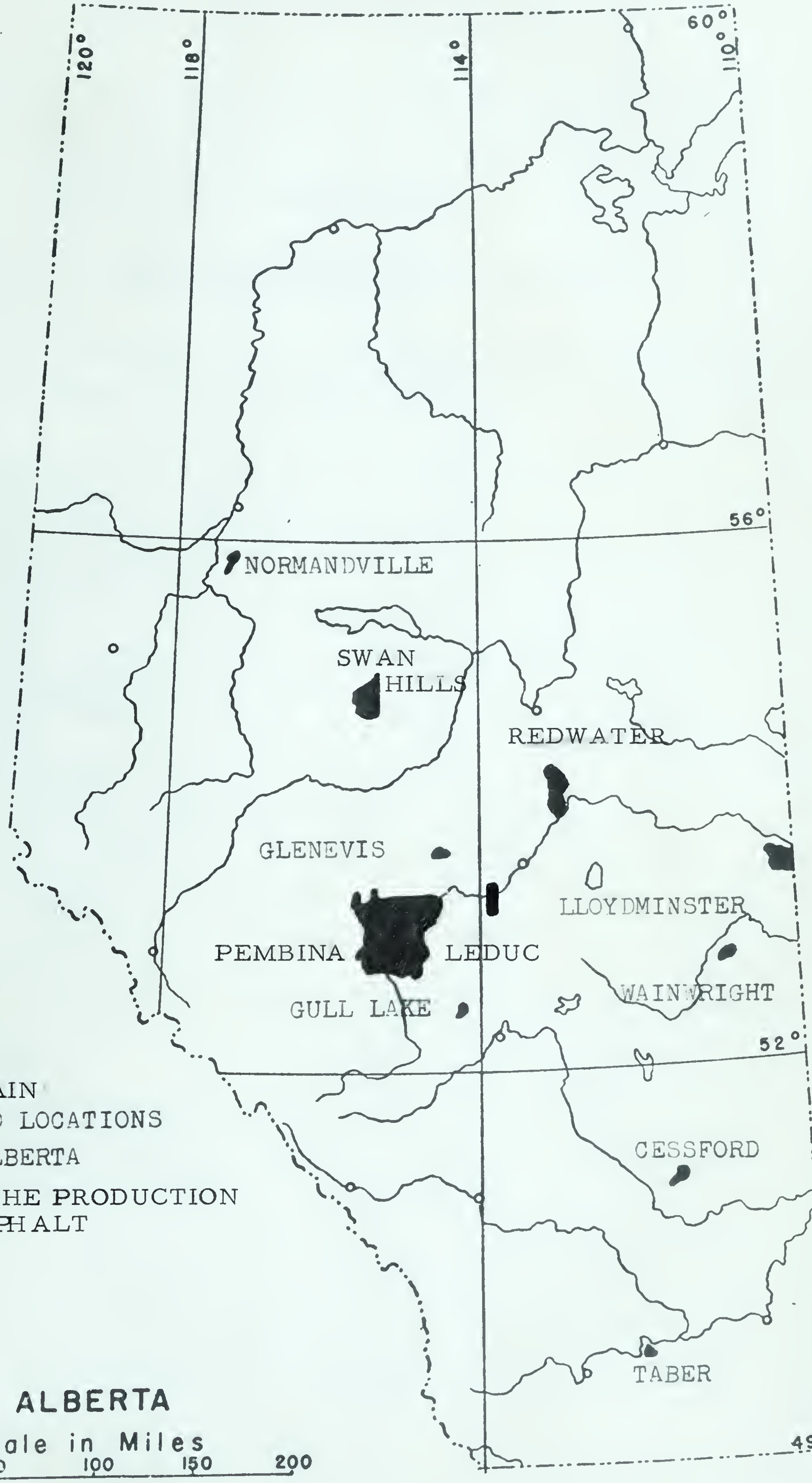
LOCATION AND CHARACTERISTICS OF OIL

USED IN ALBERTA ASPHALT PRODUCTION

Field	Pool	API Gravity	Nature of The Oil
Lloydminster	Blackfoot area, Lone Rock area	15.2°	Heavy
Wainwright	Wainwright	22°	Heavy
Lloydminster	Sparky Sand	13° - 18°	Heavy
Alberta mixed	East Taber	18.4°	Heavy
Heavy	West Taber	22.7°	Heavy
Taber, Conrad	Conrad	25.2°	Medium
Glenevis	Glenevis	18.4°	Heavy
	Lone Rock	15.9°	Not listed
	Gull Lake	22.7°	Not listed
	Normandville	21.2°	Light
Miscellaneous heavy crude Predominately Cessford		23.7°	Medium

TABLE VI

Company	Location Of Refinery	Source Of Crude Oil
Imperial Oil Limited	Calgary	Taber, Conrad, Glenevis
The British American Oil Company Limited	Calgary	Cessford
Husky Oil & Refining Ltd.	Lloydminster	Lloydminster
Wainwright Producers & Refiners Limited	Wainwright	Wainwright
Canadian Kodiak Refineries Ltd.	Lloydminster	Lloydminster, Blackfoot, Lone Rock



MAIN
OILFIELD LOCATIONS
IN ALBERTA
USED IN THE PRODUCTION
OF ASPHALT

FIGURE 7

TABLE VII

TESTS PERFORMED ON THE ASPHALT

Refinery	No. 1	No. 2	No. 3	No. 4	No. 5
Test					
Penetration at 77°F	X	X	X	X	X
Penetration at 32, 77 & 115°F	X				X
Ductility at 77°F	X	X	X	X	
Ductility at 39.2°F					X
Flash Point	X		X	X	X
Viscosity		X	X	X	
Viscosity at 275°F				X	X
Specific Gravity	X		X		X
Solubility	X		X	X	X
Softening Point	X		X		
Thin Film Oven Test & Penetration				X	X
Oliensis Spot Test		X			
Loss on Heating	X				
API Gravity			X		
Flexibility			X		
Impact Resistance			X		
Resistivity			X		
Melting Point		X			
Water by Distillation		X			
Ash	X				
% Sulphur	X				

a refinery testing program need not necessarily coincide with the present day asphalt specifications, it should, however, include such tests that can be partially related to mixing operations and service life of asphalt.

2. TESTING PROGRAM

The testing program included the following tests:

1. Penetration at 77°F, 100 gm. 5 seconds,
2. Ductility at 77°F, 5 cm. per minute,
3. Softening point,
4. Flash point, Cleveland Open Cup,
5. Specific gravity,
6. Thin film oven test and penetration of the residue,
7. Penetration at 39.2°F, 200 gm., 60 seconds,
8. Saybolt furol viscosity at 210°F,
9. Saybolt furol viscosity at 275°F.

The first five tests were performed according to America Society of Testing Materials Standards.[28] The significance of these tests was mainly to identify the asphalt. The last four tests were performed so that a prediction or a definite conclusion could be arrived at as to how the asphalt would behave during its service life.

The penetration test carried out at 39.2°F followed the standard procedure except that a cold temperature bath was used to store the sample in prior to testing. The other differences in procedure were in the apparatus, where the standard penetrometer had to be operated manually in order that a 60 second period could be employed and a 200

gram weight was used instead of the standard 100 gram weight.

The thin film oven test is very similar to the A.S.T.M. loss-in-heat test except that the size of the containers differed.[(8)]* In the thin film oven test procedure, the asphalt is placed in an aluminum container 5.5 inches inside diameter by 3/8 inch deep thus giving a film thickness of about 1/8 inch. The dimensions of the container used in the loss on heat test are 2.17 inches in diameter by 1.38 inches deep.

*McLeod, p. 46.

CHAPTER VII

TEST RESULTS AND THEIR SIGNIFICANCE

Since the size of sample supplied by the refining companies was only one gallon the results of the testing program will be only indicative of the sample, however, it was assumed that the sample was representative of the total asphalt produced by each particular company.

The results of the testing program are listed in Table VIII. These results will be discussed in relation to present specifications and correlation to field performance.

1. RELATIONSHIP TO SPECIFICATIONS

The specifications that the test results will be related to are listed in Table III. Since these specifications do not present data in 150 - 200 penetration grade asphalt, the 120 - 150, 200 - 300 penetration grade asphalt specifications will be used as boundary limits in determining the approximate order of values for a 150 - 200 penetration grade asphalt.

Penetration at 77°F. The results of this test were all within the specified limits as set forth by The Asphalt Institute. The first three results were closely grouped at 161 while the material supplied by refinery No. 4 had a penetration of 184. This difference may be accounted

for by the control each refinery used in its blending operations. Location of the crude oil source used by refineries 1, 2 and 3 were from the Lloydminister-Wainwright area while refinery 4 derived its crude from the Taber, Conrad, Glenevis areas.

Ductility at 77°F. This test gave results all in excess of 60 cms. Although there isn't any specified ductility value for 150 - 200 penetration grade asphalt, the 60 cm. figure used was taken from the 120 - 150 penetration grade asphalt where it is used as a lower limit.

Softening Point. The results of this test, although not usually specified, give another measure of consistency of an asphalt. Today more use of the test is with regard to the "penetration index" as devised by the Shell Development Company.(17)

The relationship between the softening point and the standard penetration of an asphalt cement is as follows; the higher the penetration value the lower the softening point temperature. This relationship was partially evidenced when the penetration and softening point results of asphalt No. 4 were compared with the asphalts of Nos. 1, 2 and 3.

Flash Point. The results of this test were all in excess of 400°F which was set as the minimum value.

Specific Gravity. Although this test is not called for by specifications it is of importance in its relationship to void ratio computations in mix design practice.

Penetration at 39.2°F. The usual reason this test is performed is to compare it with a penetration result at 77°F. The usual ratio is as follows:

$$\text{Penetration ratio} = \frac{\text{penetration at } 39.2^{\circ}\text{F, 200 g, 60 sec.}}{\text{penetration at } 77^{\circ}\text{ F, 100 g, 5 sec.}}$$

Although The Asphalt Institute places no specification limits on this ratio, the relative result is considered to be a measure of the temperature susceptibility of an asphalt cement.

Thin Film Oven Test. The results of this test give the percent loss or gain in weight of an asphalt sample that has been heated for five hours at 325°F.

The usual specification requirement is a 1% maximum loss. The material tested all gave a percent loss in weight which was less than 1%.

Penetration of the Residue. This is the most significant part of the thin film oven test. By comparing the penetration of the original sample with the penetration of the residue, a percentage is obtained that is a measure of the degree of hardening that took place during the test. The current specification covering this percentage is between 42 percent plus for 120 - 150 penetration grade asphalt cements and thirty-seven percent plus for 200 - 300 penetration grade asphalt cements or approximately 40 percent plus for 150 - 200 penetration grade asphalt cement. This given figure is the minimum percentage of original penetration that the asphalt cement should retain. All the asphalts passed this giving an overall range in values from 50.4 percent to 63.1 percent.

Viscosity at 210°F. The results of this test, although not that significant, are used in determining the temperature-viscosity characteristics of the asphalt.

TABLE VIII

RESULTS OF ASPHALT TESTS

Name	No. 1	No. 2	No. 3	No. 4
Test				
*Penetration at 77°F	161	162	161	184
*Ductility at 77°F	60.0+	60.0+	60.0+	60.0+
Softening Point °F	114	114	113	104
*Flash Point °F	494	530	508	647
Specific Gravity	1.001	.997	1.007	1.01
Penetration at 39.2°F	75	68	107	33
*Thin Film Oven Test. % Loss in Weight	.62	.14	.2	.4
*Penetration of the residue	81	89	85	116
Saybolt Furol Viscosity at 210°F	950	755	1176	630
*Saybolt Furol Viscosity at 275° F	80	97	123	80

*Designates test specified by The Asphalt Institute Specifications, 1960 edition.

TABLE IX

CODE

Refinery No.	Refinery
1	Kodiak
2	Wainwright
3	Husky
4	Imperial Oil
5	B. A.

Viscosity at 275°F. The results of this test were all greater than 60 saybolt-furol seconds, the minimum allowed by the specifications. The range of values recorded were from 80 to 123 S.S.F.

2. CORRELATION TO FIELD PERFORMANCE

As was stated in Chapter V, Part II, the first five tests in the testing program were merely for identification and safety purposes. The remainder of the tests, although not all specified, will be discussed in their relationship to predicting field performance. This performance will begin during the mixing operations of the asphalt, and continue until the asphalt is in place in the field.

Mixing Operations. This operation is based upon the viscosity of the asphalt, and what temperature is necessary to attain this viscosity or degree of fluidity. In many hot-mix plants, an upper limit temperature of 325°F is specified. The upper limit temperature of 325°F, which is usually used in fall and late fall paving will render some asphalts less viscous than others, depending on the asphalt's temperature-viscosity characteristics. Figure 8 shows the results of the temperature viscosity characteristics of the four 150 - 200 penetration grade asphalts tested. The limits used for optimum viscosity for plant mixing are 100 to 150 saybolt furol seconds, although some authorities specify 75 to 150 Saybolt furol seconds.[14] Utilizing these characteristics, the temperatures necessary to attain the optimum mixing viscosity in this case 125 S.S.F. for the materials 1, 2, 3 and 4 are 273°F, 277°F, 288°F and 245°F, respectively. Since these temperatures are below 325°F the film thickness

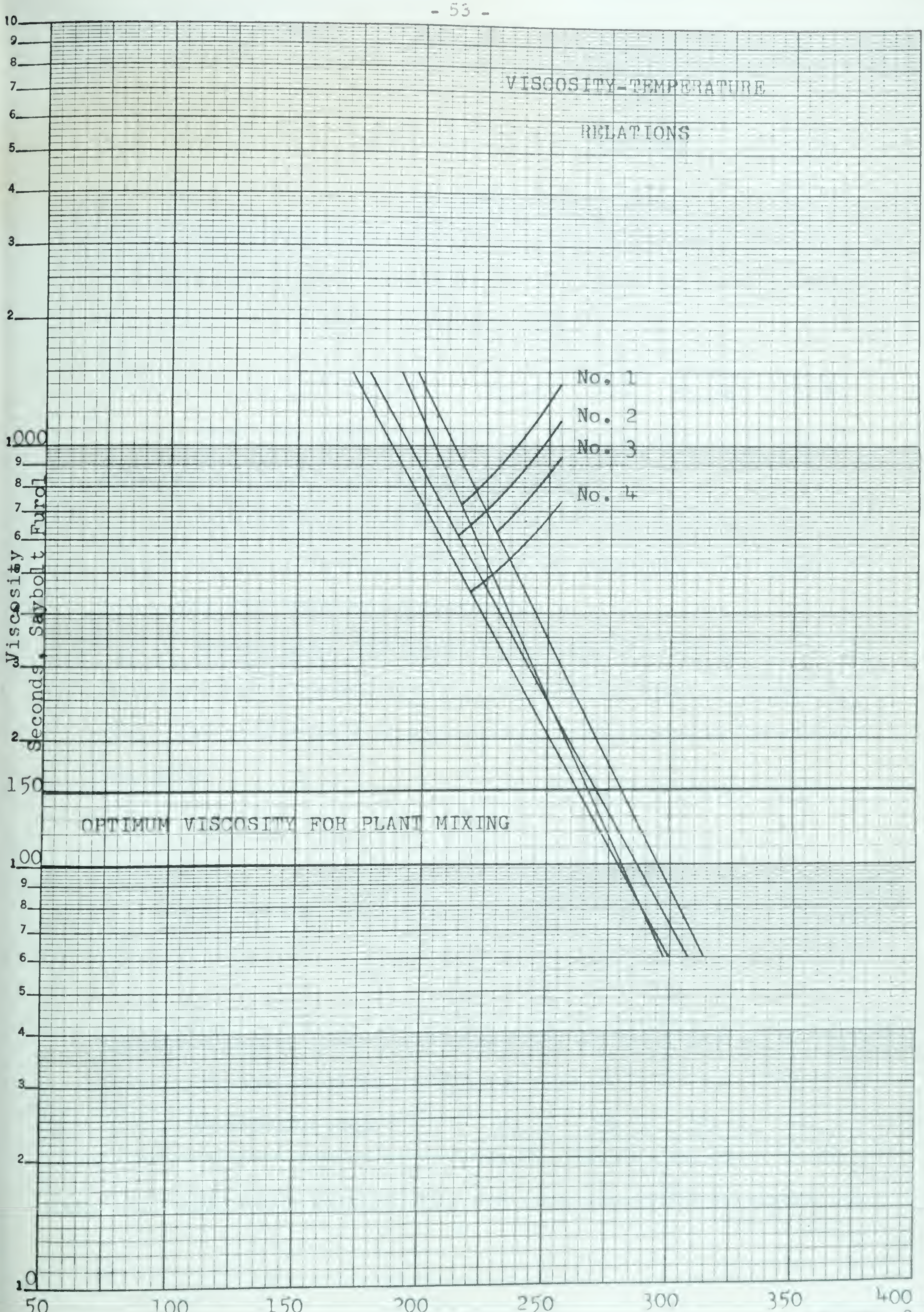

VISCOSITY-TEMPERATURE
RELATIONS
No. 1
No. 2
No. 3
No. 4
OPTIMUM VISCOSITY FOR PLANT MIXING
Viscosity
Seconds, Saybolt Furol
1000
150
100
10
50
100
150
200
250
300
350
400
TEMPERATURE °F

FIGURE 8

of the asphalt coating the aggregate would be much thicker than if the mixing temperature was in the neighborhood of 325°F.

The actual amount of hardening is measured by the thin film oven test through comparison of the before and after penetrations on a per centage basis. These are listed as follows:

	1	2	3	4
Percent of Original Penetration	50.4%	55%	52.8%	63.1%

Under the conditions of the test, the penetration of the four asphalts were reduced by forty to fifty per cent.

The significance of these results and their correlation is hardening due to overheating is limited because the conditions of test procedure and mixing operations vary considerably.

<u>Service Life</u>. The asphalt's performance on its service life has been measured by its decrease in penetration with decrease in temperature. This measurement is expressed in a ration known as the penetration ratio:

$$\text{Penetration ratio} = \frac{\text{penetration at } 39.2^{\circ}\text{F, 200 g., 60 sec.}}{\text{penetration at } 77^{\circ}\text{F, 100g., 5 sec.}} \times 100$$

This is considered to be a measure of the temperature susceptibility, although there is very little evidence that this is actually related to field performance. In some parts of the U.S.A. this ratio has been included in asphalt cemntspecifications with the lower limit set at 25%.[29]

The results of this ratio are as follows:

	No. 1	No. 2	No. 3	No. 4
Penetration ratio	46.5%	42.0%	66.5%	18.0%

The lower the percentage, the more susceptible the asphalt will

be to temperature change.

In view of the extremes of pavement temperatures in Canada, the more temperature-susceptible the asphalt, the greater will be the brittleness at lower temperatures. Specifications do not contain a temperature-susceptibility requirement because of the lack of data relating the pavement performance to temperature-susceptibility.

CHAPTER VIII

CONCLUSIONS

The following conclusions may be drawn from the literature review.

1. The petroleum crude oil best suited for the production of asphalt should have an API gravity of less than 33°. Under these conditions the steam and vacuum distillation refining process are more applicable. If the petroleum crude oil is semi to non-asphaltic in nature, or in other words its API gravity is greater than 33° the oxidation or air-blowing process is commonly required for asphalt production.
2. It has been seen with regard to past asphalt cement specifications that more attention was paid to the writing of tests for identification purposes and the measurement of inherent physical properties. Today, the trend is gradually changing from an identification specification to a quality measurement specification. The principal criterion of asphalt cement quality is the manner in which it performs in a road surface.

With reference to the testing program the following conclusions may be drawn:

3. Results of all tests conducted on the four asphalt cements met the specifications in the 1960 Edition of the Asphalt Institute Manual. The tests for solubility in carbon tetrachloride and ductility at 60°F were not performed.

4. The differences in results as noted by the thin film oven test and the penetration ratio may be due to the source and characteristics of the petroleum crude or crudes used in the production of each particular asphalt cement. This lack of uniformity in results was also noticed in the flash point test. A more definite conclusion may have been drawn if an asphalt sample had been obtained from refinery No. 1 which also uses a mixture of petroleum crude oils in the production of its asphalt cement.

CHAPTER IX

RECOMMENDATIONS

Recommendations as a result of this study are as follows:

1. Correlation between pavement performance and laboratory asphalt cement tests. This would involve a correlation between asphalt cement test results performed at definite stages throughout the asphalt pavement's life and the performance of the pavement at that time. With these results a more accurate prediction could be made on the performance of a bituminous pavement.
2. Information with regard to asphalt composition and its correlation to pavement performance. Although this may lessen the authority of the present asphalt cement tests, it should enable the supplier to produce an asphalt that would be controlled by composition and that would ultimately out-perform present asphalt cements now produced.
3. Development of the penetration ratio and its measurement of temperature-susceptibility. Although this measurement has been partially taken care of with the addition of certain specifications of the Saybolt Furol Viscosity test at 275°F, it was found in this thesis that the results of the viscosity test at 275°F were quite similar, while the results of the penetration ratio varied considerably.

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APPENDIX A

CANADIAN KODIAK REFINERIES LTD.

~~es Tegler Building~~
~~monton, Alberta~~
~~one PBX GArden 4-7376~~
PHONE: 3311

LLOYDMINSTER, ALBERTA

November 23, 1960

Mr. D.W. Mitchell
110 Engineering Bldg.
University of Alberta
EDMONTON, Alberta

Dear Sir:

I shipped today one (1) gallon sample of our 150/200 S.R. Asphalt to you as requested in your letter of November 18, 1960.

Along with this letter I return the completed questionnaire to you. Your thesis subject is very interesting. When you have completed your study will you please furnish me with a copy of your thesis.

For any further information do not hesitate to contact me.

Yours truly

CANADIAN KODIAK REFINERIES LTD.

PERE Jack Van Der Meulen
(Industrial Chemist)

JM/clw

NWRIGHT PRODUCERS & REFINERS LIMITED

PRODUCERS REFINERS AND MARKETERS
BOX 728 WAINWRIGHT, ALBERTA
TELEPHONE 438

December 5, 1960 .

Mr. D. W. Mitchell,
c/o University of Alberta,
110 Engineering Bldg.
EDMONTON, Alberta.

Dear Mr. Mitchell;

We are in receipt of your letter of November 18th requesting information regarding our companies operations in the asphalt field and a sample of our 150/200 pen asphalt. We are pleased to answer your questionnaire form and you will find it attached to this letter. A one gallon sample of our current 150/200 penetration asphalt is being shipped to you by rail and you should receive it shortly.

We wish you success in your thesis and we would appreciate receiving a copy of your thesis when it is finished.

Yours truly,

WAINWRIGHT PRODUCERS & REFINERS LTD.

Ronald A. Stuart

Ronald A. Stuart,
Refinery Manager

RAS/ew.

HUSKY OIL & REFINING LTD.

PRODUCERS · REFINERS
MARKETERS

Lloydminster, Alberta,
November 25, 1960.

Mr. D. W. Mitchell,
110 Engineering Building,
University of Alberta,
EDMONTON, Alberta.

Dear Sir:

In reference to your letter of November 18th, 1960, we are returning the completed questionnaire and hope that the information supplied will be of assistance to you.

We are also forwarding to you by C. N. Express a one-gallon sample of 150 - 200 Penetration Asphalt; our Sample Number 1957.

Yours very truly,
HUSKY OIL & REFINING LTD.,

V. O. Juba,
Plant Chemist.

VOJ:GC
cc: L. W. Cavanagh.

THE BRITISH AMERICAN OIL COMPANY LIMITED

PRODUCERS - REFINERS - MARKETERS

800 BAY STREET, TORONTO 5, ONTARIO

December 13, 1960.

Mr. D.W. Mitchell,
University of Alberta,
110 Engineering Bldg.,
Edmonton, Alberta.

Dear Mr. Mitchell:

I am returning your questionnaire as requested basing my information on Alberta operations. As you are possibly aware we do not make asphalt at our Edmonton Refinery, the information therefore applies only to Calgary.

I trust this information will be of value to you. We would be interested in seeing a copy of your thesis when completed. It will not be necessary to more than loan us a copy for a short period.

Yours very truly,

E.T. Hignell ljm

E.T. Hignell,
Asphalt Technologist.

ETH/ljm
Att.

IMPERIAL
Esso
PRODUCTS

IMPERIAL OIL LIMITED

MANUFACTURING DEPARTMENT

P.O. BOX 818, CALGARY, ALBERTA

T. REYNOLDS
EFINERY MANAGER

December 28, 1960

C.L.R. 1331 - (8.1)

Request for Information
and Sample -
University of Alberta
D.W. Mitchell

Mr. D. W. Mitchell
110 Engineering Building
University of Alberta
Edmonton, Alberta.

Dear Sir:

The one gallon sample of 150/200 Penetration Asphalt which you requested is being sent by C.P.R. Express, prepaid, December 28, 1960 under our outgoing number C-541-60.

Your questionnaire form has been completed and is attached. Both of these items were covered by your November 18 letter.

We are very interested in hearing that you are preparing and writing a thesis titled "The Significance of the Present Day Asphalt Specifications and What Effect the Crude Oil Source and the Refining Process has on the Engineering Properties of the Asphalt". You may be sure that we are looking forward to receiving a copy of your work and that, within reason, we will be glad to cooperate with you to the end of its being completed.

We have taken some liberty in answering your questionnaire form. Rather than list what tests are performed on the finished asphalt product we are referring you to the "Asphalt Handbook", Manual Series No. 4, March 1960 from which our specification inspections program is taken. The tests given in this manual are common in the industry and are normally made in their entirety. Further, you will appreciate that no single source of crude oil covers our asphalt production. Our sources are many and vary from year to year and even during the asphalt season. All but a few Alberta crude oils of 30.0 A.P.I. Gravity or less may be made to produce a residium having adequate quality for asphalt. Even some crude oils of higher than 30 A.P.I. Gravity will produce asphalt quality residium. Our choice of crude oils is made primarily on the basis of their cost and the total realization of products anticipated.

Rather than attempt to comprehensively describe our entire asphalt production scheme which would represent a paper in itself, we have answered only the questions asked. We would be glad to supply further information

C.L.R. 1331 - (8.1)   December 28, 1960

providing, of course, it does not include confidential items. Any questions you ask are referred to our Manufacturing Management in Toronto for clearance, consequently, some delay will very likely occur if you ask for further information.

Yours very truly,

IMPERIAL OIL LIMITED

S. T. REYNOLDS

By: C. F. McCullagh/R.S.K

C. F. McCullagh

CFMcCullagh/lh

Attach.